

HELIOTEK

A Division of **Textron** Inc.

12500 GLADSTONE AVE., SYLMAR, CALIFORNIA 91342 • TWX 910-496-1488 • Area Code 213/365-6301



~~N 70 16874~~

NASA CR 105857

N70-11446

Development of Lithium Diffused

Radiation Resistant Solar Cells

Report No. 3

First Quarterly Report

**CASE FILE
COPY**

By: P. Payne
H. Somberg

15 October 1969

JPL Contract No. JPL 952547

This work was performed for the Jet Propulsion Laboratory,
California Institute of Technology, as sponsored by the
National Aeronautics and Space Administration under Contract
NAS7-100.

Heliotek, a Textron Company

12500 Gladstone Avenue

Sylmar, California

Manufacturers of Space Age Solid State Devices

This report contains information prepared by Heliotek, a Textron Company, under JPL subcontract. Its content is not necessarily endorsed by the Jet Propulsion Laboratory, California Institute of Technology, or the National Aeronautics and Space Administration.

SUMMARY

During this first quarter, the boron diffusion was the principal area of investigation. This is an important phase of this contract since areas of the lithium cell investigation are dependent upon obtaining a relatively stress free boron diffusion, which is impossible with the BCl_3 diffusion typically used.

Experiments to investigate various material parameters were also designed.

The first lot of lithium cells was fabricated and delivered to JPL and an output analysis is included in this report.

TABLE OF CONTENTS

<u>Section</u>	<u>Description</u>	<u>Page</u>
1.0	Introduction	1
2.0	Technical Discussion	3
2.1	Boron Diffusion Studies	3
2.2	Material Studies	6
2.3	Cells for Shipment	8
3.0	Conclusions	12
4.0	Recommendations	13

LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Description</u>	<u>Page</u>
1	Elementary Diffusion System,	4
2	Comparison of I-V Characteristics of 1 ohm cm P/N Cells.	7
3	Short Circuit Current Distribution of Lithium Cells Fabricated for the First Lot (66 cells).	10
4	Maximum Power Distribution of Lithium Cells Fabricated for the First Lot (66 cells).	11

INTRODUCTION

The goal of this contract is to investigate the effect of various process parameters on lithium doped solar cell performance. This program is a continuation of work done on JPL contract 952247, and it has been organized into five areas of study. The five basic areas include: P-N diffusion studies, material studies, lithium diffusion studies, special structure studies and contact studies. As much as possible, these areas will be worked on concurrently; however, the P-N diffusion studies will be done during the first four months since certain aspects of the lithium diffusion and special structure studies will be dependent upon progress made with the P-N diffusion.

The purpose of the P-N diffusion studies is to develop a boron diffusion which; 1) does not etch silicon, 2) will yield higher efficiency lithium cells due to reduced stresses and 3) can be used for larger area and thinner cells (also due to reduced stresses).

As part of the material studies parameters such as oxygen content, crystal growth rate and blank thickness will be investigated.

The lithium diffusion studies will be directed toward improving cell efficiency and obtaining maximum radiation damage recovery. Radiation studies conducted under JPL contract by other laboratories during the past year have shown in one limited experiment that long lithium diffusions done around 325°C result in higher efficiency and more radiation resistant lithium cells. These diffusion parameters as well as the process techniques of complete lithium coverage of the back cell surface and lithium evaporations were used in fabricating the cells that showed unusually good radiation recovery, so these same parameters will be further investigated in this program in order to determine if these results can be reproduced.

The contact studies will include evaluation of the Ti-Ag contacts presently used as well as investigation of other contact metals

such as Pd and Ag.

The special structures to be studied will be lithium cells with integral covers and a lithium cell with a high concentration N^+ region at the junction.

In addition to the experimental studies, 600 lithium doped solar cells will be fabricated for radiation testing and analysis by JPL.

2.0 TECHNICAL DISCUSSION

2.1 BORON DIFFUSION STUDIES

During the first quarter of this contract a boron diffusion system was investigated using the liquid impurity source boron tribromide. A schematic of the system is illustrated in Figure 1. Following the preliminary diffusions conducted during this period large variations existed in the sheet resistance measurement for any given diffusion. Hot point probe checks indicated the existence of a stratified impurity flow during diffusion. Observation of the diffusion process itself appeared to offer evidence of a laminar flow condition and a concentration gradient within the flow pattern.

A series of diffusions were performed to delineate the laminar flow-stratified layer problem in the following manner:

1. Diffusions were performed at three temperatures (900°C, 1055°C, 1125°C) to examine the temperature effect on the convection of gases and the formation of concentration layers.
2. At each temperature a matrix of variables, namely diffusion time, cell position and gas flow rates were evaluated to observe the effects of these parameters on cell performance.

2.1.1 Temperature Variation

In this experiment, two groups of cells were diffused at each temperature mentioned above; one group was placed vertically and one horizontally in the diffusion boat. Identical diffusion times and gas flow rates were used in each case.

At each temperature a non-uniform glass layer resulted and essentially no difference was noted between the cells in the vertical and horizontal placement. While the horizontally diffused cell blanks had a less accentuated nonuniformity when measured with the hot point probe, the presence of an "N" deflection was always prevalent. In the groups that were vertically diffused there was a more pronounced difference in

ELEMENTARY DIFFUSION SYSTEM USING A LIQUID IMPURITY SOURCE

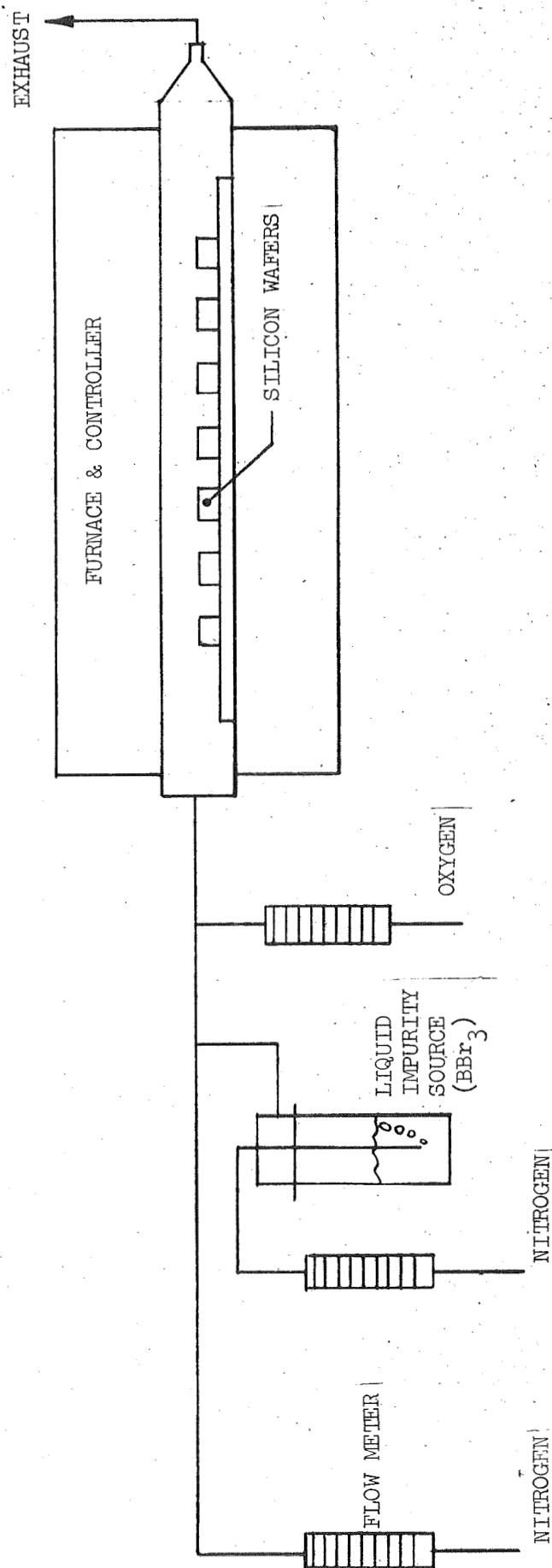


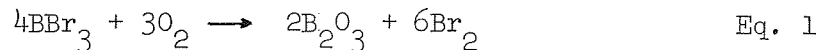
FIGURE 1

the location of the "N" and "P" deflections. While a strong "P" deflection occurred at the top of the cell, the lower half became more strongly "N" especially at the cell blank diffusion boat interface. Consequently it was concluded that there was essentially no difference in the concentration nonuniformity as a result of the variation in temperatures. The stratified layer, therefore, does present a problem in providing even distribution of the boron impurity in the furnace tube.

2.1.2 Variations in Diffusion Parameter Matrix

In this series of experiments an entire family of gas flow and time variations was performed.

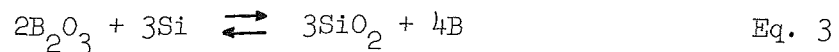
One significant consideration was the effect of the transport and reactant gas concentration. In this system oxygen is used to react with the liquid impurity to form the local source,



and also reacts with silicon to form its oxide,



The O_2 concentration can be critical since an excess reaction with silicon will reduce the availability of silicon to react with the local impurity oxide to form the elementary impurity at the surface,



Low oxygen concentrations in Eq. 2 shifts to the left providing more silicon available to react in Eq. 3. The reverse of this (i.e., greater O_2 concentration) would leave little silicon available for the formation of free boron in Eq. 3 and this provides a large concentration of B_2O_3 in the glass layer and little diffusant available at the surface. Since the segregation coefficient favors

the B_2O_3 remaining in the glass layer ($x SiO_2 - y B_2O_3$), the solution to this problem lies in the resolution of the gas flows into the proper concentrations.

When high N_2 flow rates were used (1500 cc/min) nonuniformity in the glass layer was predominant. After glass layer removal an insoluble discoloration remained which could only be dissolved in an etchant that reacted with silicon itself. When diffusions were made in a reducing atmosphere (i.e., using only N_2 with the impurity liquid) an insoluble gray-black deposit resulted on the chemically polished surface.

Using larger O_2 flows resulted in a uniform glass layer and its removal left no deposits. The polarity, however, ranged from "P" to "N" as previously mentioned. When nitrogen was eliminated entirely during the diffusions and low oxygen rates were used, uniformity of the glass layer prevailed. In some of these cases using a horizontal cell blank placement, the resultant polarity was complete and uniform "P".

In experiments where the diffusion time was varied, a short diffusion of about ten minutes offered the most promising results. In Figure 2 are I-V characteristics for cells diffused by two different methods. The upper curve was a result of the BCl_3 diffusion in a reducing atmosphere using cells with a mechanically lapped surface. The lower curve is from a BBr_3 diffusion in an oxidizing atmosphere using chemically polished cells. These curves indicate the importance of determining the proper diffusion conditions. Although good diffusions with a BBr_3 source have been made, the diffusions have not been optimum and further variations in the system will be necessary.

2.2 MATERIAL STUDIES

The experimental work to investigate various material parameters has been designed and initial material procurement started. Included in the plan are experiments to study the effects of crystal growth rate on oxygen content and dislocation count. In addition, oxygen content measurements will be obtained on various ingots of crucible

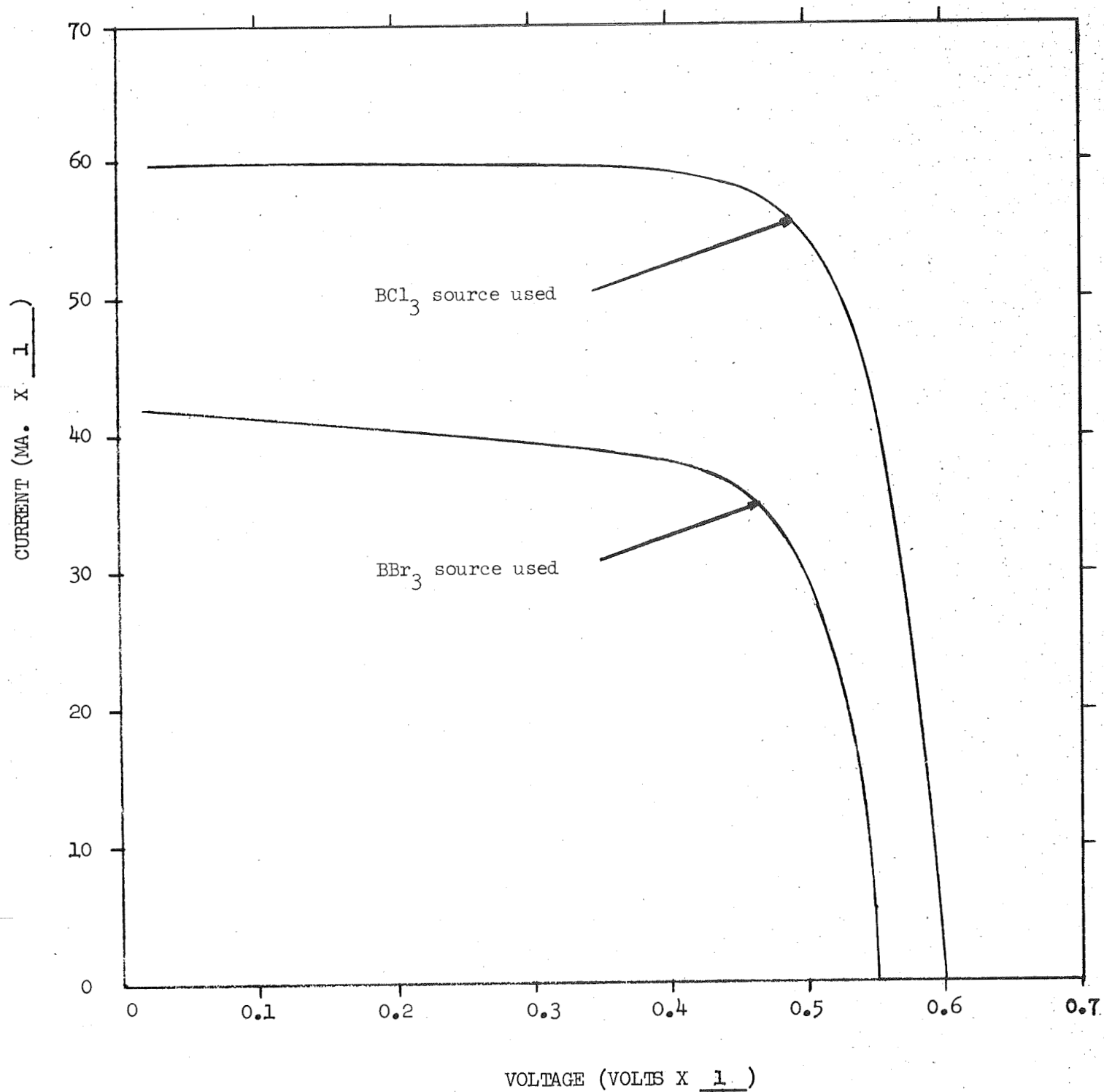


Figure 2. Comparison of I-V Characteristics of 1 ohm cm P/N Cells.

grown, float zone, and Lopex silicon grown by standard techniques to evaluate the degree of variation in oxygen content.

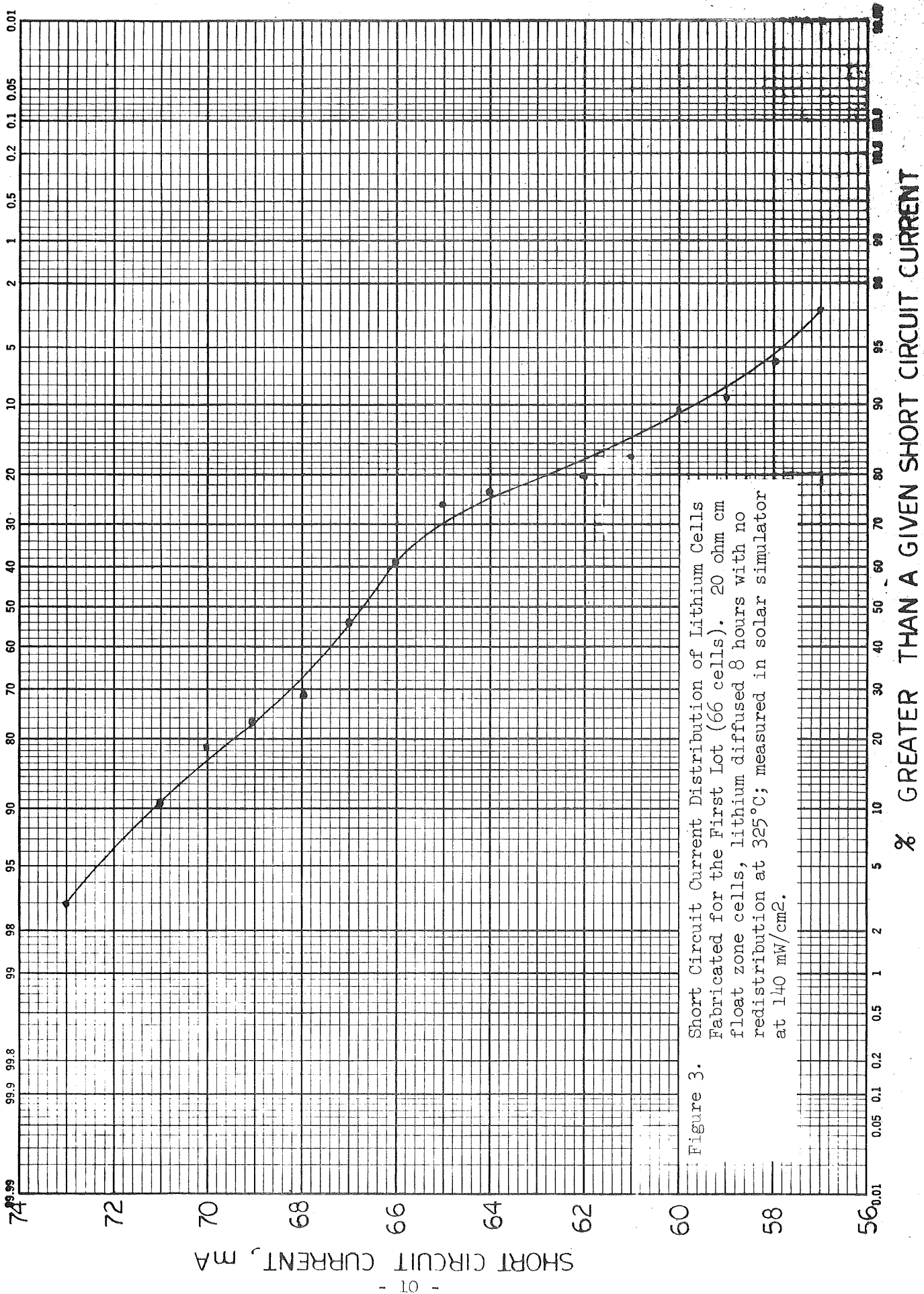
The effects of cell thickness on lithium cell characteristics will also be studied. For example, cells of various thicknesses would be diffused the same length of time in order to evaluate the effect of thickness. Also, an experiment will be performed in which the lithium diffusion time will be varied in order to correlate diffusion time and lithium concentration to cell thickness.

2.3 CELLS FOR SHIPMENT

The first shipment of experimental cells has been delivered to JPL. It consisted of sixty cells fabricated from 20 ohm cm float zone silicon. The cells were lithium diffused eight hours at 325°C. No redistribution or sintering was performed. These cells were the first ones diffused longer than two hours. Some of the problems, such as severe pitting of the silicon surface and cell breakage, which were previously encountered and eliminated in the shorter diffusions reappeared in the long diffusions. This problem was solved by painting a thinner layer of lithium on the cell surface. However, this solution indicated that another factor might also be a problem in the long diffusions. The four point probe V/I values varied with the thickness of the lithium layer. In some cases the cells with thicker lithium layers had V/I 's ten times lower than cells with thinner lithium layers. This has not been a problem with shorter diffusions (two hours or less) and might result in significant variations in cell performance and radiation resistance. If this problem is significant it will probably be able to be eliminated by evaporating lithium onto the cells rather than painting. This technique of lithium deposition will be investigated because it is felt that the thickness of the lithium layer could be controlled far more accurately with evaporation. The short circuit current of the eight hour diffused cells varied much more than normal and many did not have good curve factors. Many of the cells had rounded I-V curves. The reason for this is unknown at present

and insufficient time was available to fully investigate this loss and still provide eight hour diffused cells for the first shipment of experimental cells. Before further shipments of similar cells, investigation must be done to evaluate lithium concentration, I-V characteristics, and effects of redistribution or sintering.

More than one hundred cells were started through lithium diffusion; however, due to pit-induced breakage, variations in the diffusions, and shunting effects, only 66 cells were used for the maximum power and short circuit cumulative frequency distributions (Figures 3 and 4). The following statistics were obtained for the short circuit current. 5% were ≥ 72.3 mA, the mean was 66.7 mA, and 95% were ≥ 57.7 mA. With respect to the maximum power, 5% were ≥ 28.3 mW, the mean was 25.5 mW, and 95% were ≥ 23.6 mW. The average output of these cells was approximately 3% lower than the average output of 20 ohm cm float zone cells diffused 90 minutes and redistributed 60 minutes at 425°C . Cells with this type of diffusion have been known to exhibit very high output. However, the range in output was relatively narrow and further investigation as well as improvements in the processing techniques should result in higher efficiency cells.



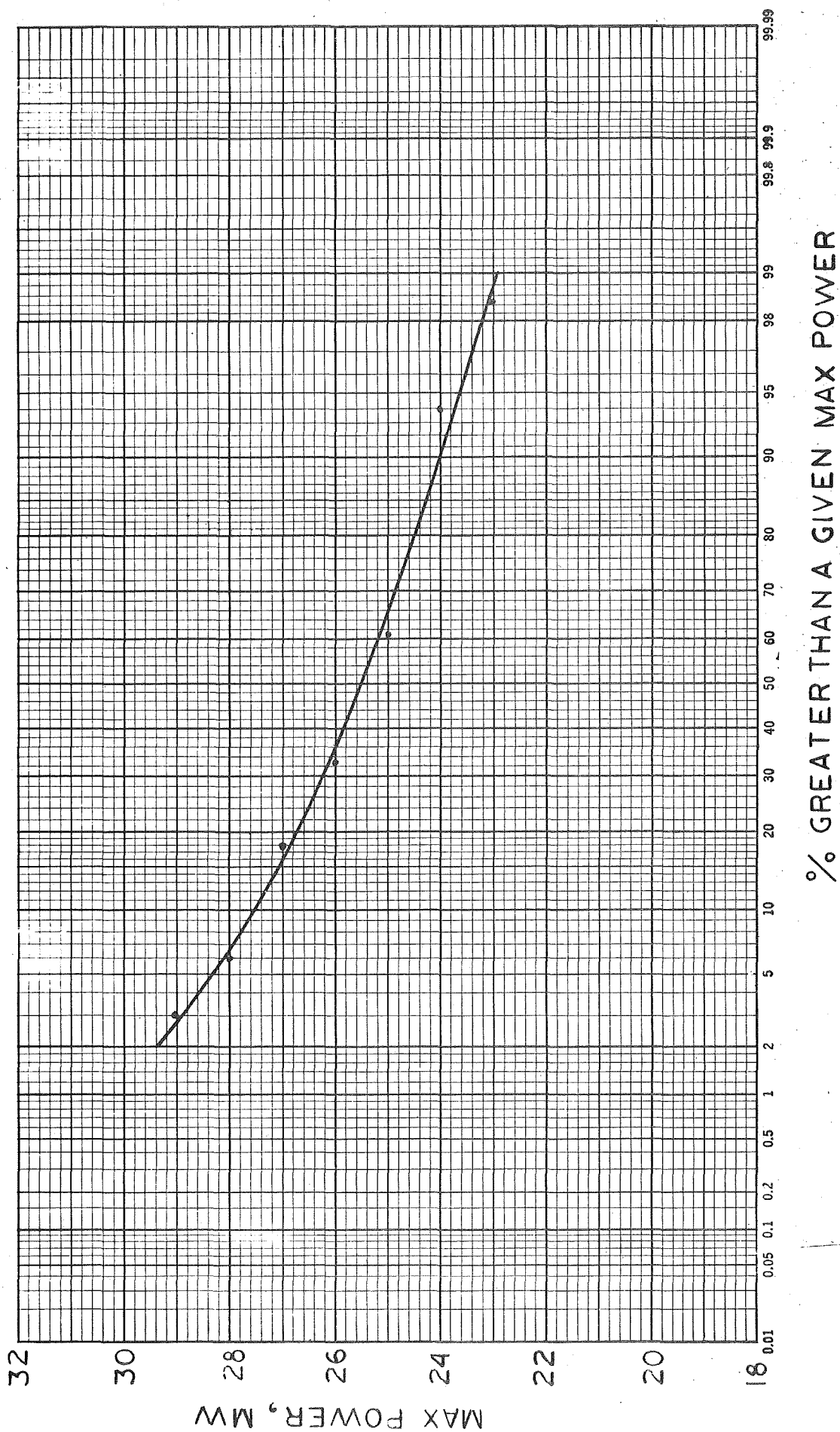


Figure 4. Maximum Power Distribution of Lithium Cells Fabricated for the First Lot (66 cells).
 20 ohm cm float zone cells, lithium diffused 8 hours with no redistribution at 325°C
 measured in solar simulator at 140 mW/cm².

3.0

CONCLUSIONS

The BBr_3 diffusion process has shown some promise but has not yet been optimized.

The efficiencies of the lithium cells diffused eight hours were not as high as expected, however, some were quite good and should provide an interesting test sample for radiation analysis.

4.0

RECOMMENDATIONS

Not applicable.